Use of Thresholds in Landscape Assessments

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Workshop – Making the Linkages Through the Use of Environmental Indicators, 17 – 20 May, 2004

Presentation Highlights

- Briefly review the concept of thresholds and issues related to threshold establishment
- Present results of landscape studies where landscape conditions are linked to aquatic resource conditions
- Demonstrate use of statistical approaches that permit interpretation of landscape data in the context of thresholds for specific aquatic endpoints

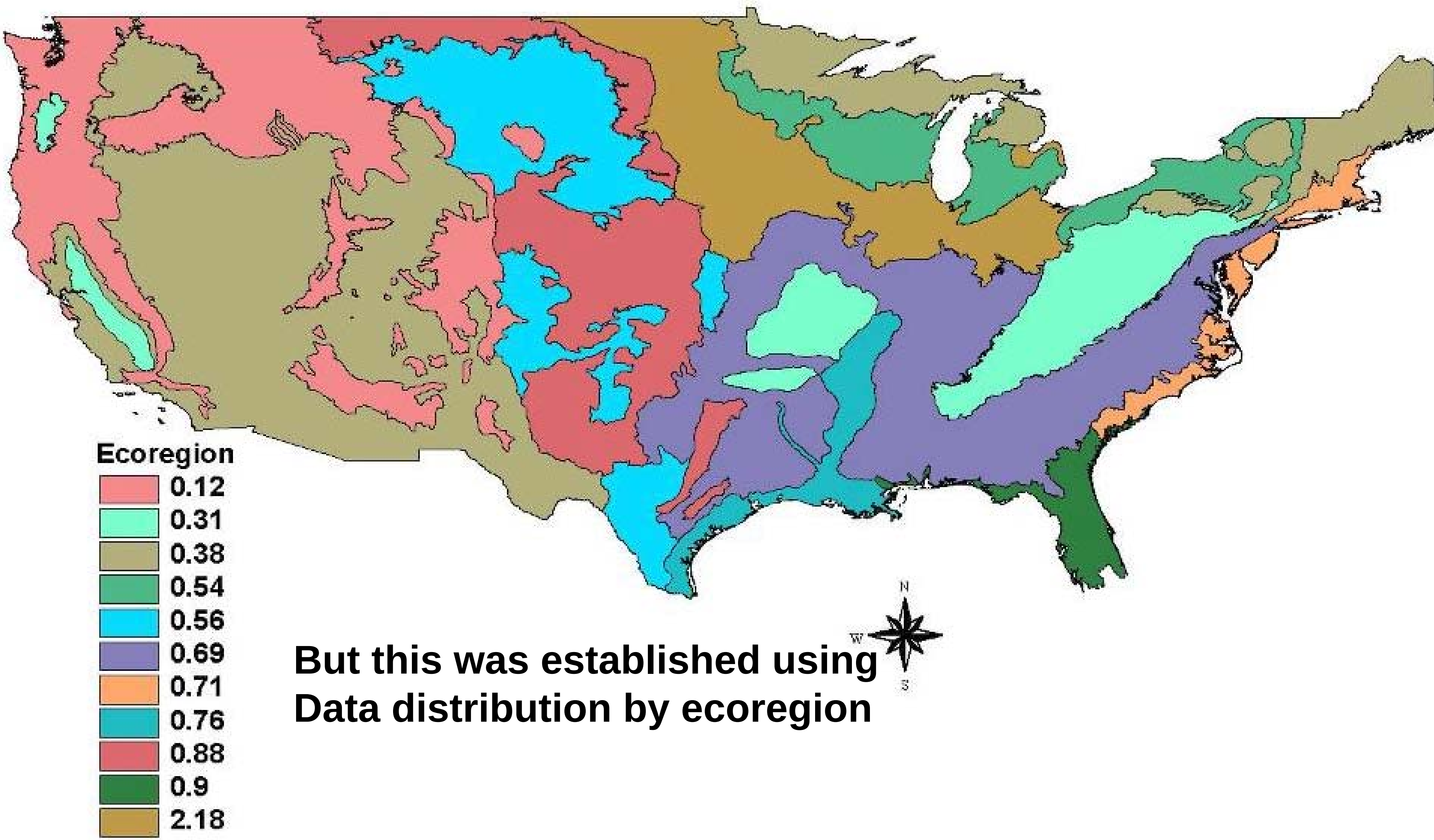
Why Do We Want to Establish Thresholds

- Evaluate resource condition and impairment
- Predict/forecast future condition and likelihood of a change to less desirable condition (generally) … transition to a state that is less desirable
- Early warning (some but not most)
- Benchmark related to risk reduction and restoration

General Types of Thresholds

- Arbitrary
- Ecologically- or Biophysically-based
  - Ecoregions
  - Reference sites
  - Gradient analysis
  - Temporal studies
- Distribution of the Data
  - Quintiles and other classifications

Total Nitrogen Concentration by Ecoregion

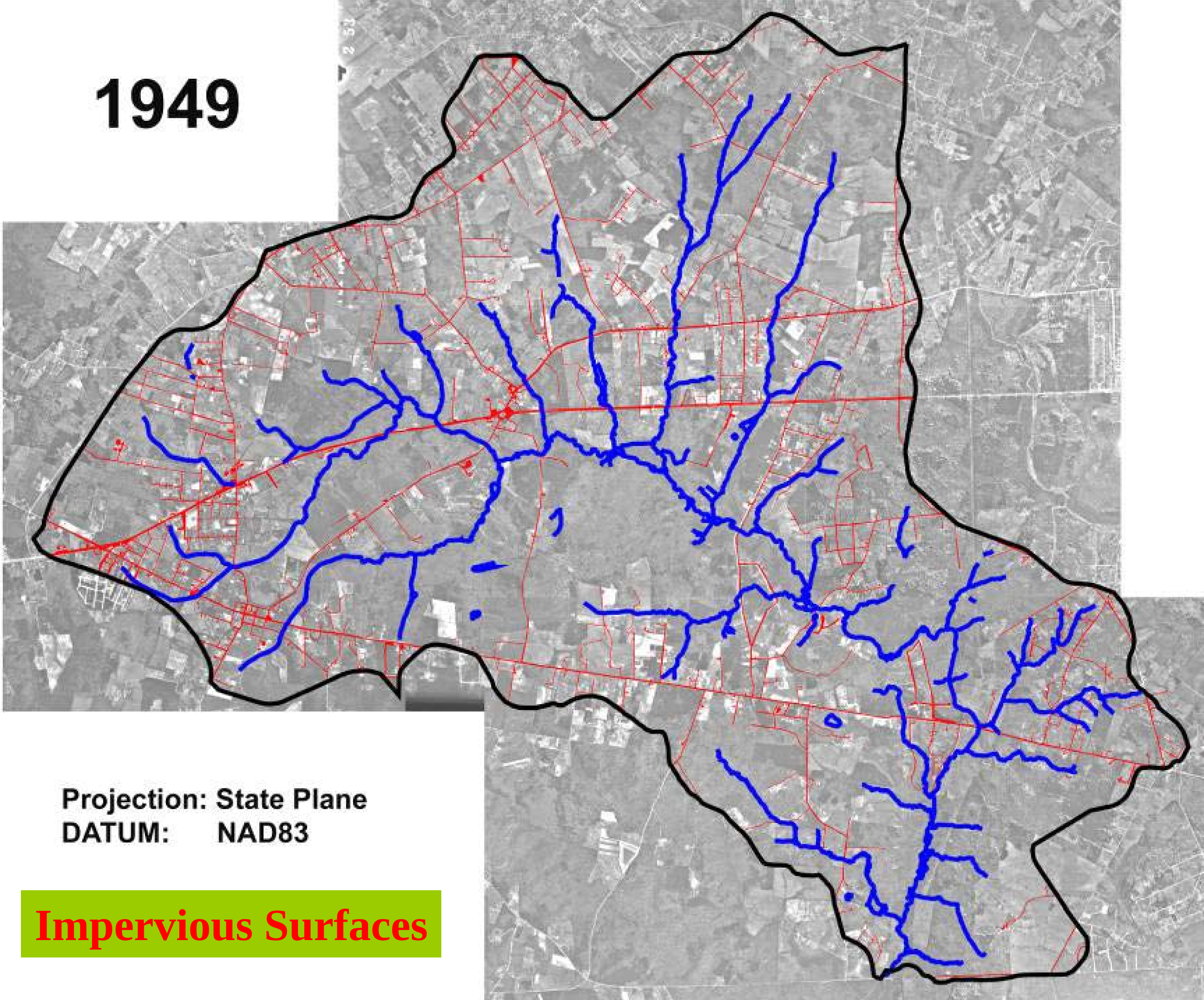


But this was established using Data distribution by ecoregion

Why Has It Been Difficult to Establish Thresholds

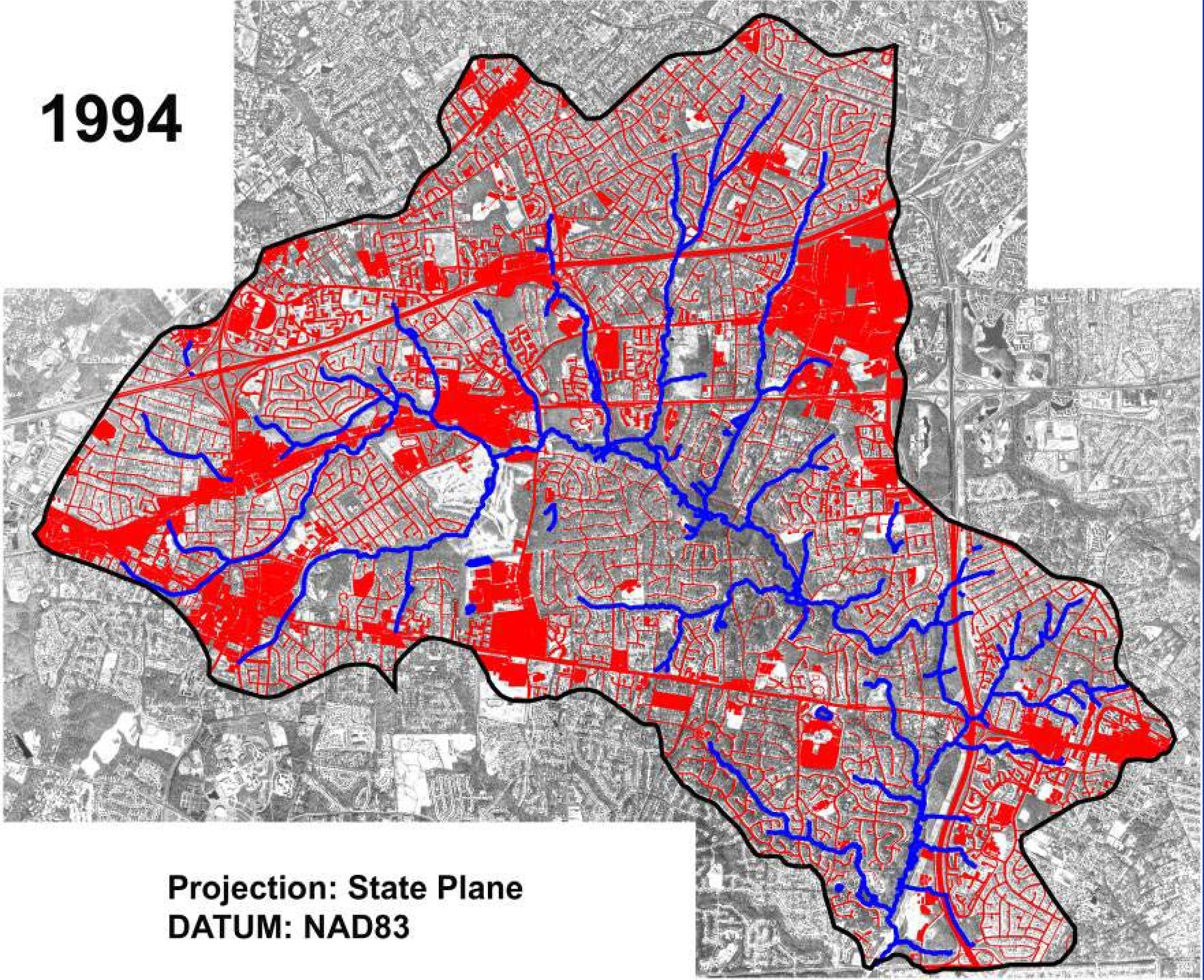
- Lack of long-term data over extensive areas
- Scaling issues … understanding constraints in space and time (in different biophysical settings)
- Complex interactions
- Initial conditions, time lags, and history
- Sequence and frequency of disturbance/drivers influences threshold levels at which phase transitions occur (to less desirable state)
- They may exist only in our minds! (should be the H^0)
- State of science allows us to understand thresholds for areas that are really stuffed … but not much beyond that.

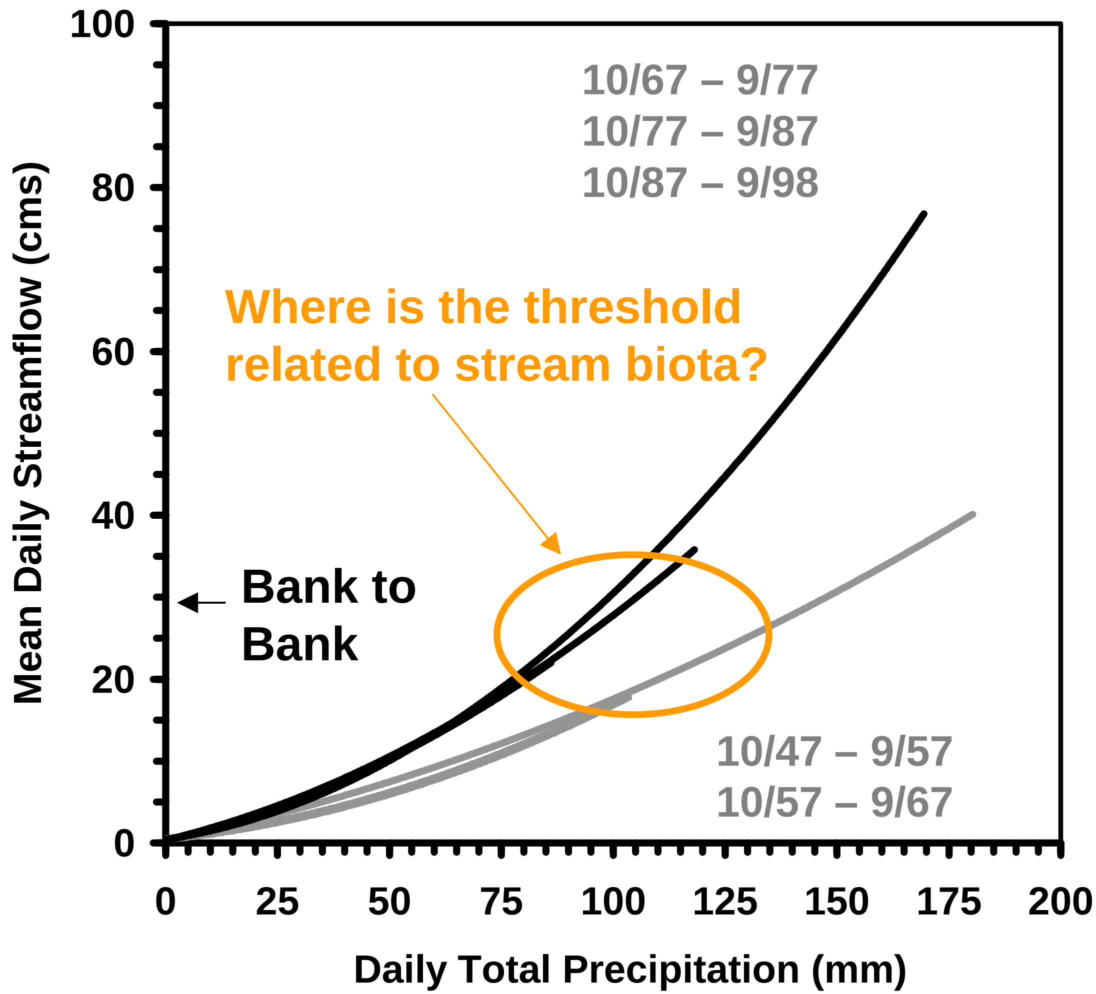
1949



Projection: State Plane
DATUM: NAD83

Impervious Surfaces


1994
Projection: State Plane
DATUM: NAD83



1947 - 1998 Streamflow vs. Precipitation

From: Jennings and Jarnagin 2003. Landscape Ecology.

Landscape Assessments and Thresholds

Primary Goals

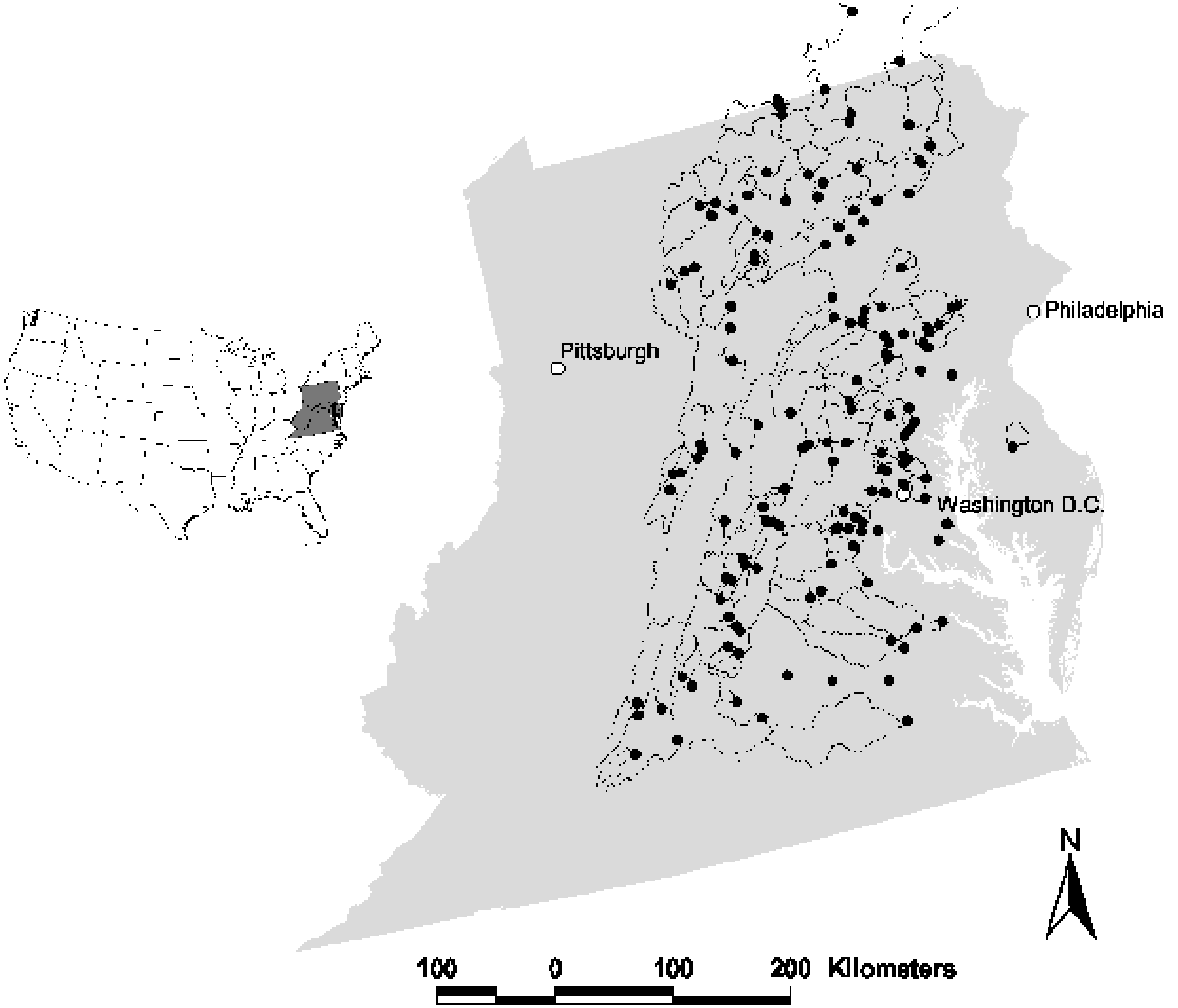
- Link landscape and biophysical conditions at multiple scales to ecological endpoints and associated processes so that we can understand how landscape condition influences condition thresholds for ecological resources of interest
- If we understand these relationships then we may be able to design landscape/watersheds to reduce risks of exceeding thresholds
- Focus mostly on aquatic resource endpoints
- Emphasis on existing data, but where possible, influence the designs of ongoing or upcoming probability samples

Statistical Approaches

- Evaluating User-Defined Thresholds
  - Logistics regression
  - Baysian
- Inductive Approaches to Determine Thresholds and Breakpoints
  - Classification and Regression Tree (CART)

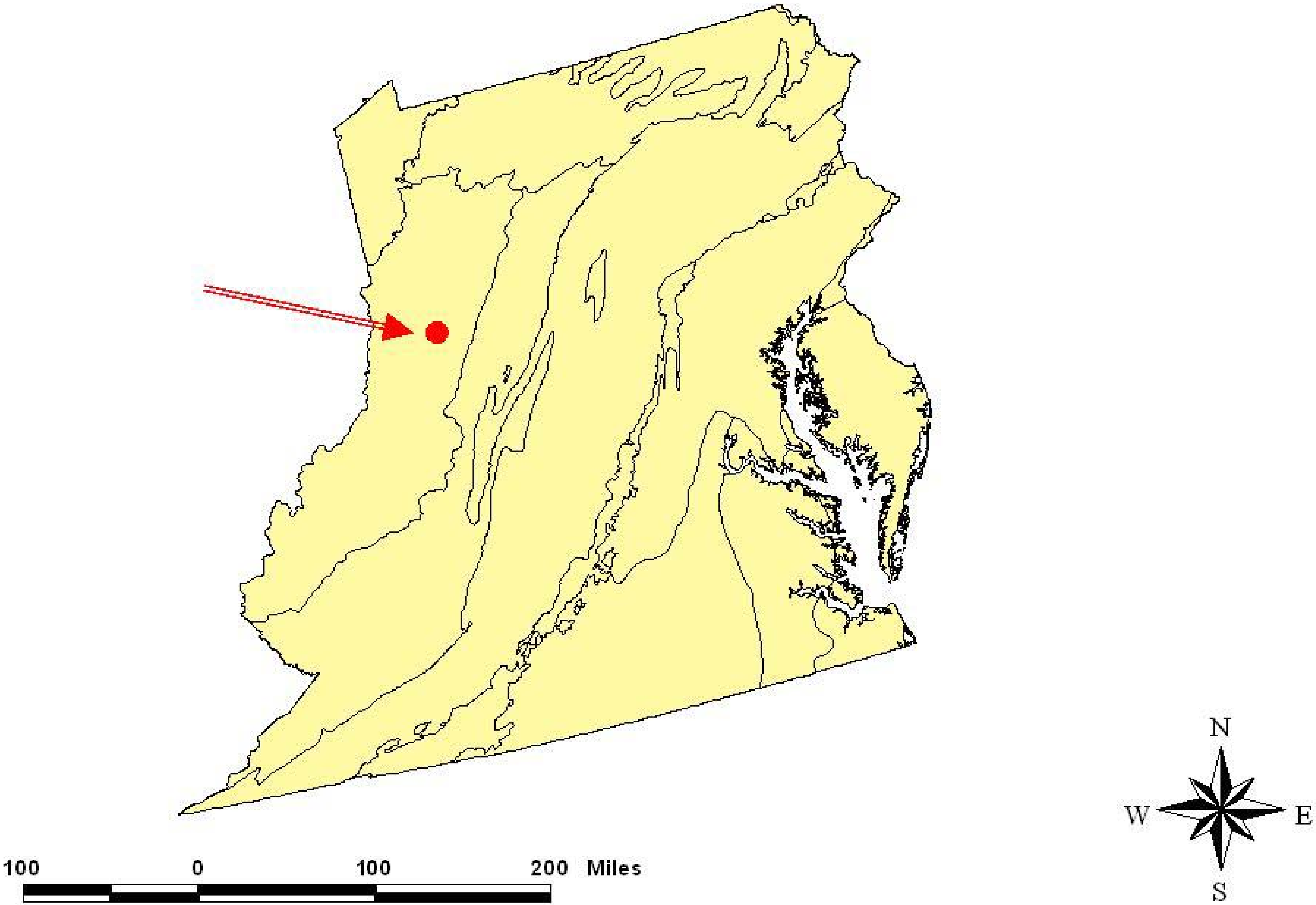
General Approach

- Select specific endpoint of interest (e.g., TMDL parameter)
- Collect/acquire field samples
- Filter data based on selection criteria
- Assemble spatial data at various scales on various units (functional and arbitrary)
- Generate metrics and/or measures … pair metrics with individual samples sites in a SAS database
- Conduct statistical analyses

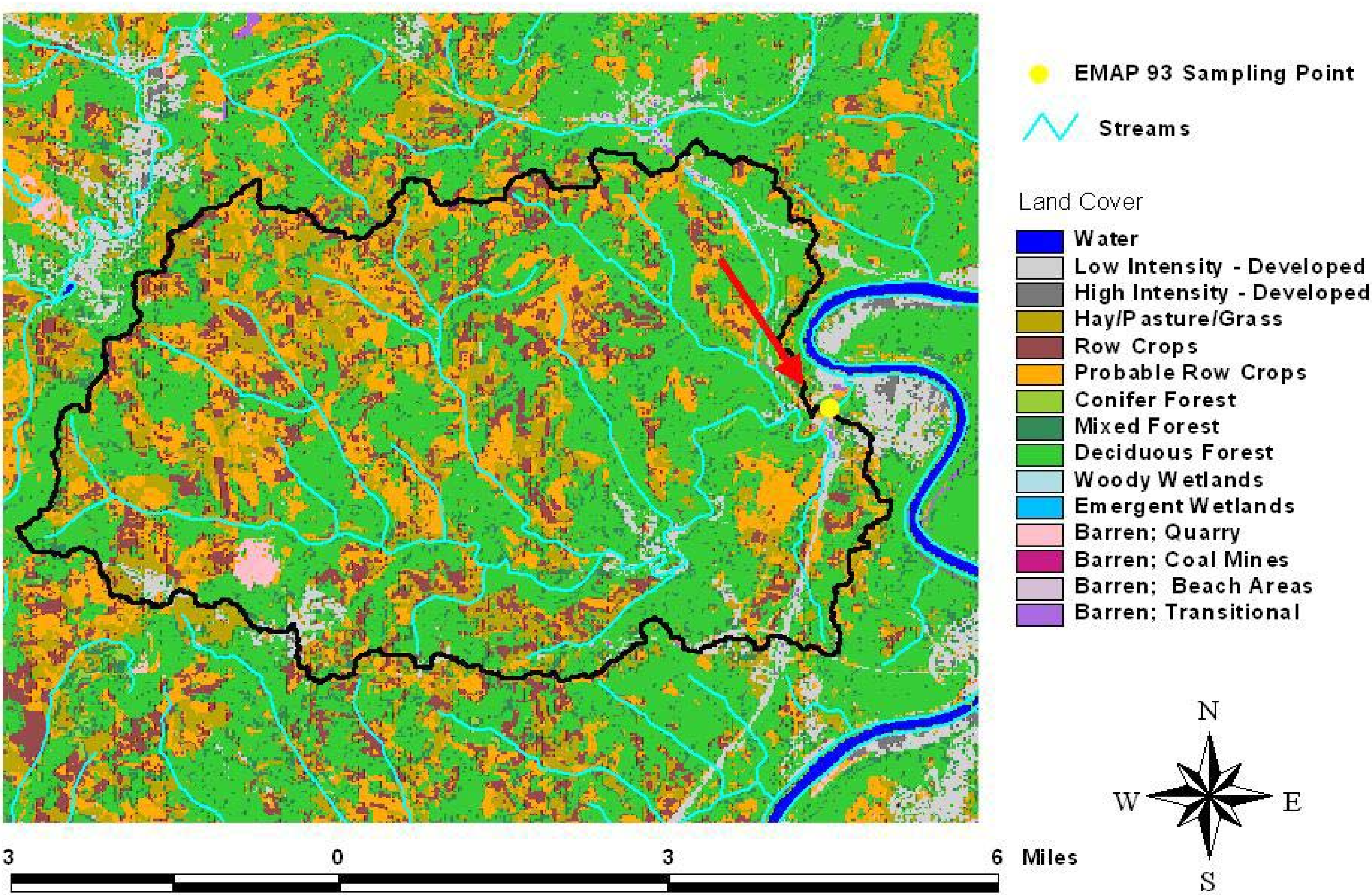


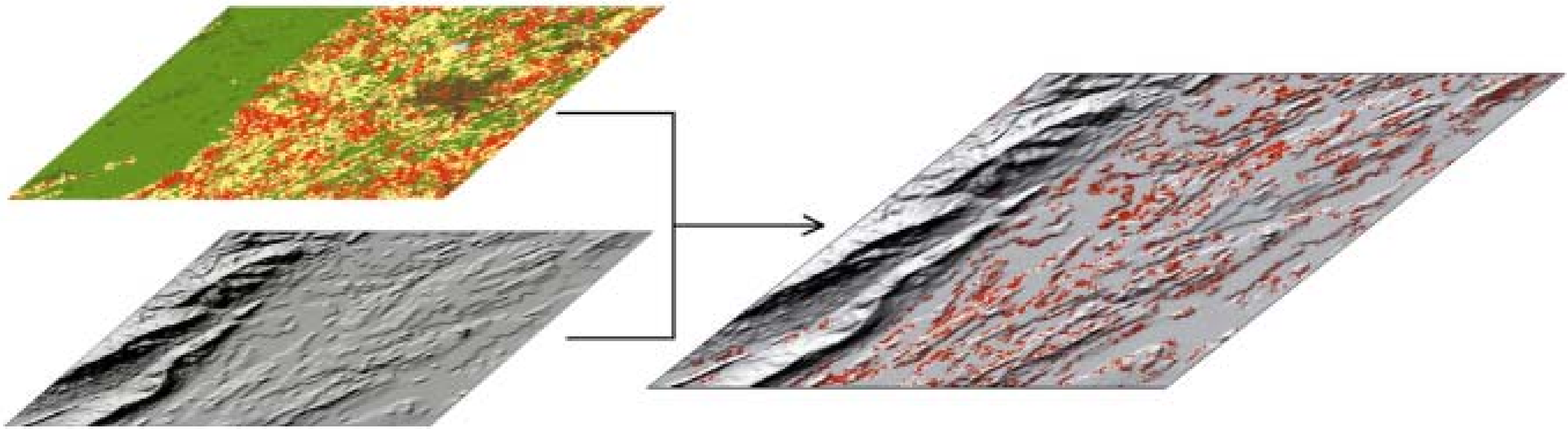
USGS Loading Sample Sites and Associated Watersheds

Location of Example Watershed

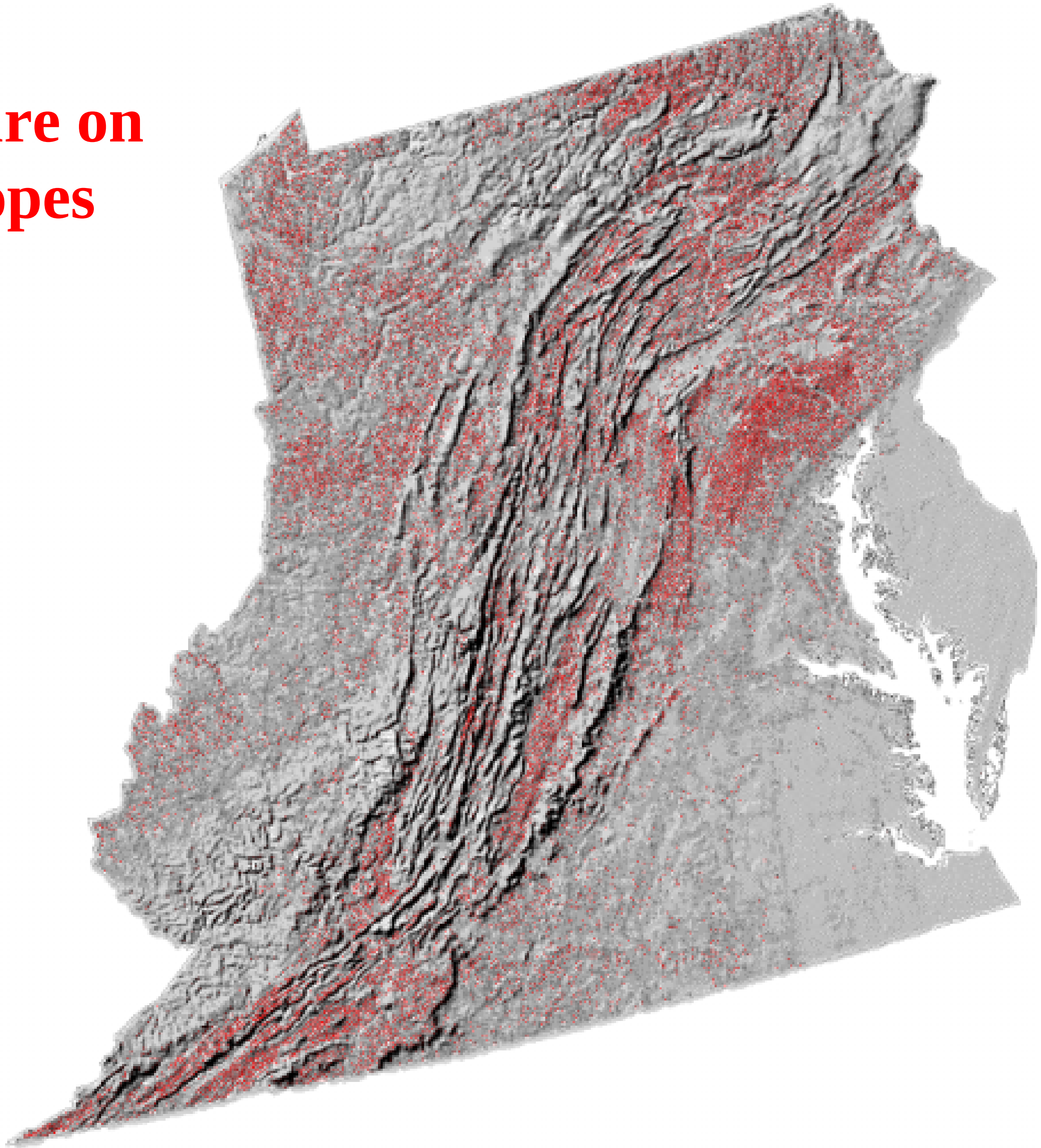


Example Watershed





Agriculture on > 3 % Slopes



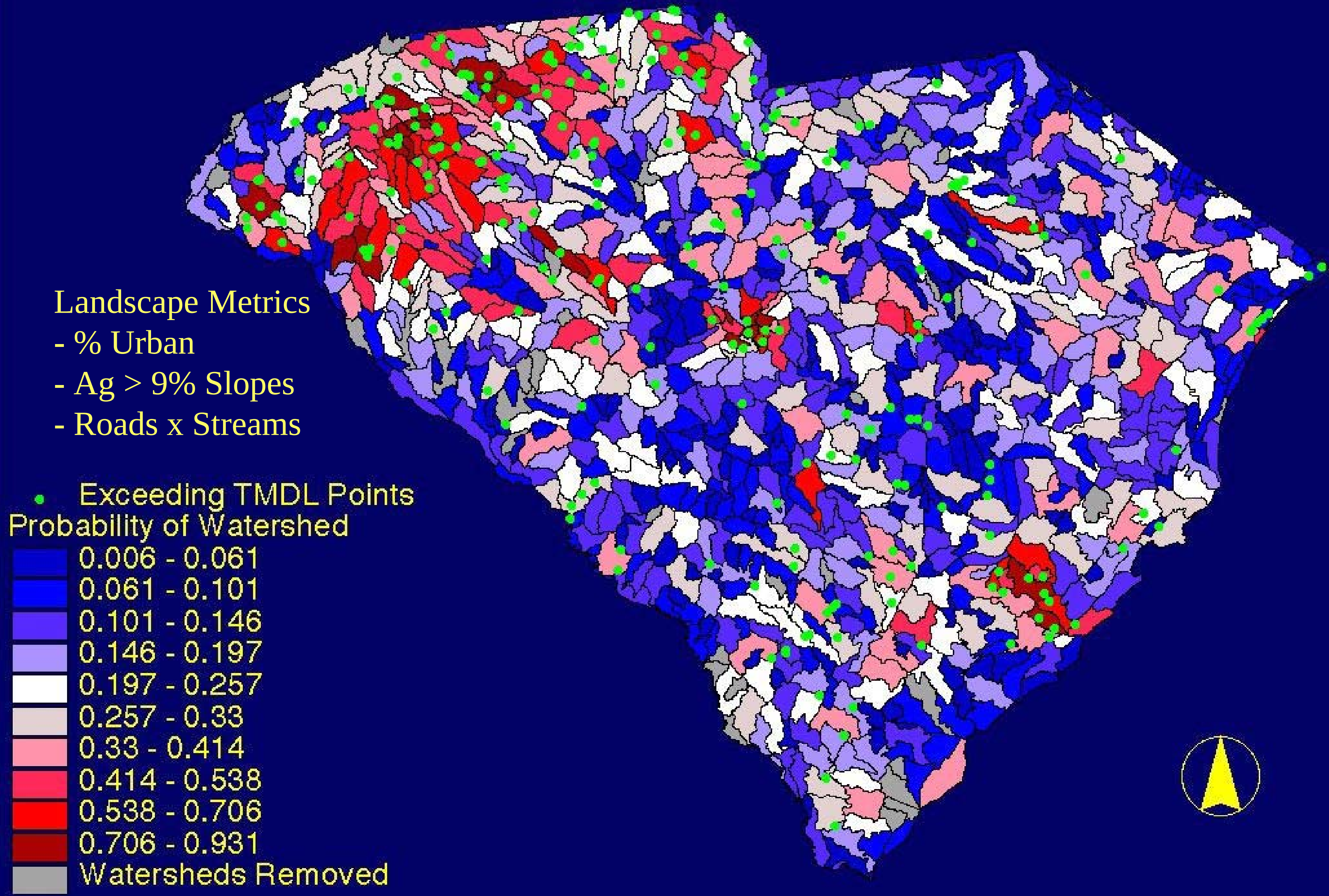
Landscape Metrics

Mean Riparian agriculture
Riparian forest
Forest fragmentation
Road density
Forest land cover
Agricultural land cover
Agricultural land cover
on steep slopes
Nitrate deposition
Potential soil loss
Roads near streams
Slope gradient
Slope gradient range
Slope gradient variance
Urban land cover
Wetland land cover
Barren land cover

Logistics Regression

- Uses threshold values and provides cross-validation and probabilities of exceeding a threshold (yes/no relative to a dependent variable) based on a set of independent variables (landscape and biophysical variables)
- Useful for evaluating probability of exceeding a TMDL threshold/condition threshold

Logistic Regression Results with Test Points



Other Applications of Logistics/Threshold Approach

- Watershed/landscape linkages with benthic indices in east coast estuaries (Steve Hale, Atlantic Ecology Division, NHEERL)
- Watershed/landscape linkages to concentrations of pesticides in sediment in Mid-Atlantic coastal streams (Ann Pitchford, Environmental Sciences Division, NERL)

Baysian Landscape Models

- Emphasis is on the use of existing data
- Can be used to evaluate probability of exceeding a threshold value for an indicator
- Jim Wickham (EPA RTP/NERL) and John Paul (EPA RTP/NHEERL) are using this approach in their work.

Nitrogen Export
kg/ha/yr

Forest	Urban	Agriculture
0.1	5.0	3.2
0.1	5.0	4.8
0.2	5.0	5.0
0.7	5.1	5.0
2.2	5.4	5.8
2.5	6.7	9.1
2.5	7.9	9.6
2.6	9.6	9.8
3.0	9.6	11.9
3.7	12.0	14.0
4.4	16.3	20.0
7.6	18.0	20.6
12.2	28.0	22.3
		23.5
		33.3

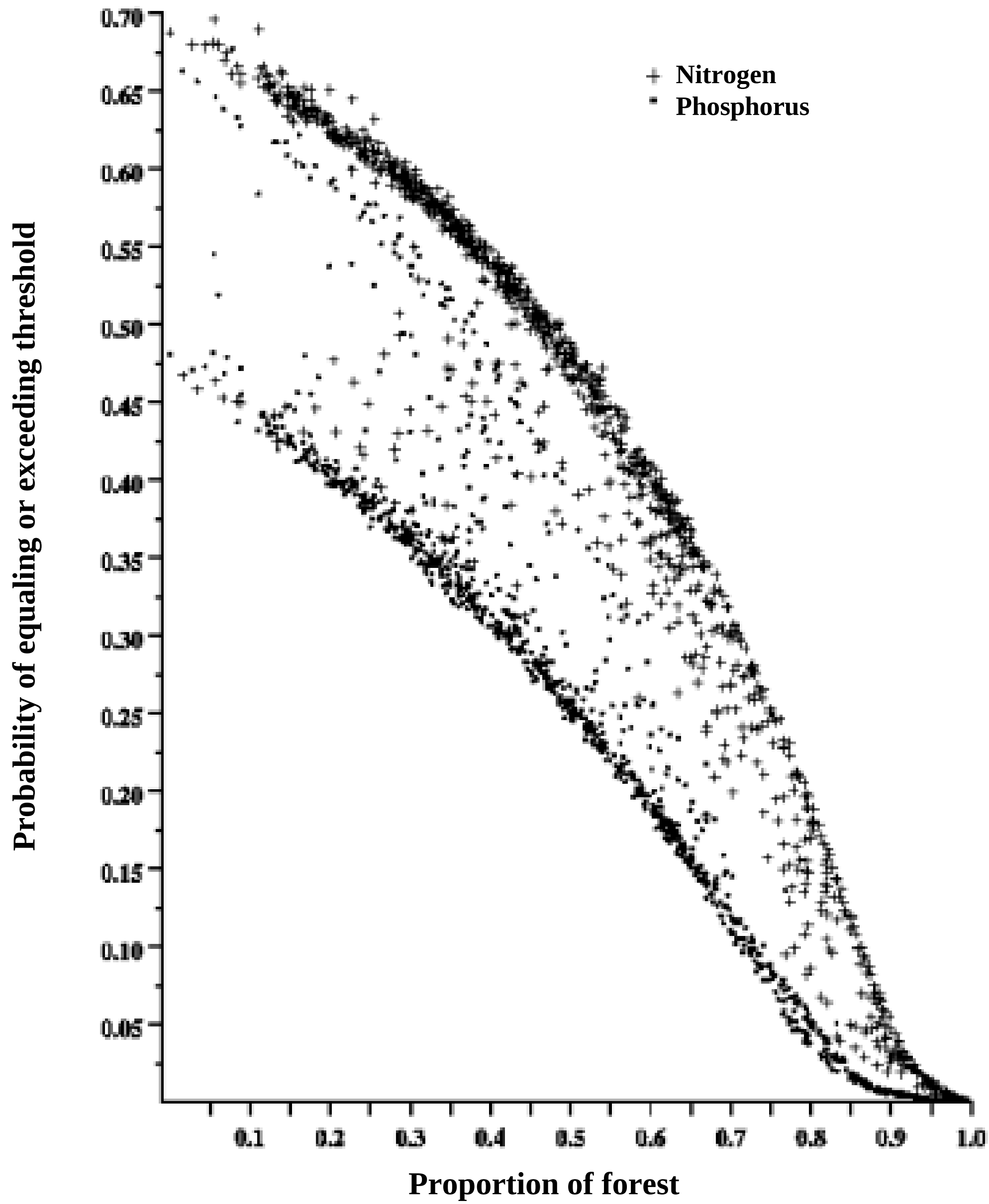
Source: Frink (*JEQ*, 1991, 20:717)

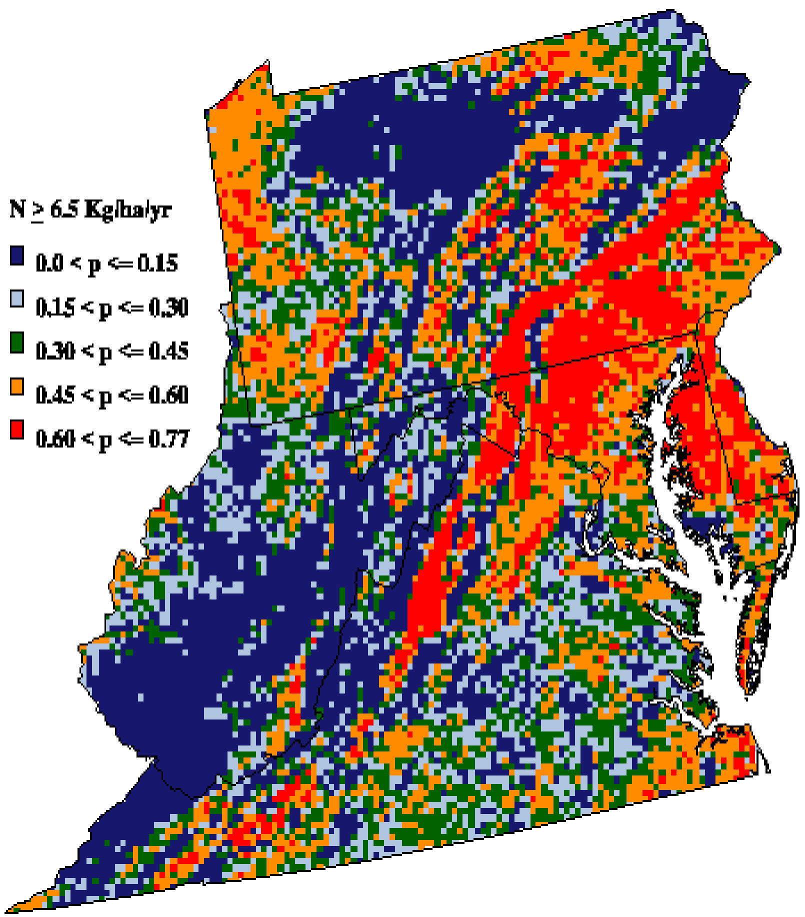
Land-Cover	WS (ha)	N/P	# of Obs.	Min	Q_{25}	Q_{50}	Q_{75}	Max
Agriculture	40-8000	N	30	2.1	6.6	11.1	20.3	53.2
Urban	4-4800	N	19	1.5	4.0	6.5	12.8	38.5
Forest	7-47000	N	21	1.4	1.9	2.5	3.3	7.3
Agriculture	40-8000	P	27	0.08	0.49	0.91	1.34	5.40
Urban	4-4800	P	24	0.19	0.69	1.10	3.39	6.23
Forest	7-47000	P	62	0.01	0.04	0.08	0.22	0.83

$$N, P = \sum_{i}^{n} (C_i * \mathrm{A}_\mathrm{i})$$

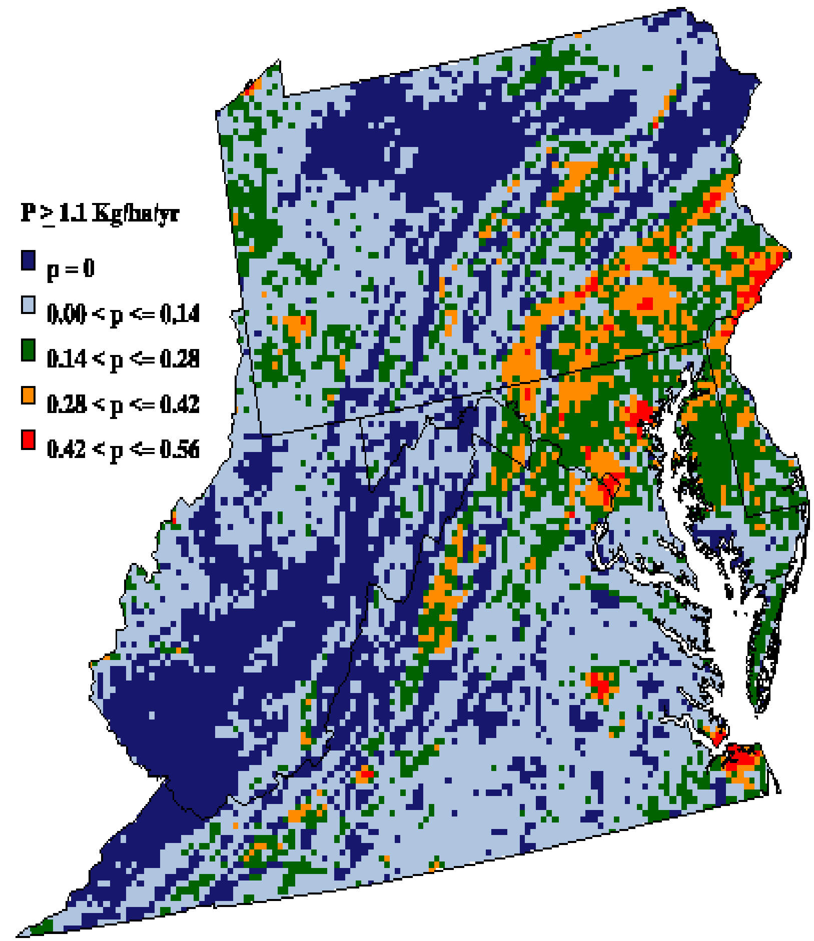
	N	P
Threshold	7.0	0.8

Risk: # of iterations / 10000 >= 7.0 or 0.8

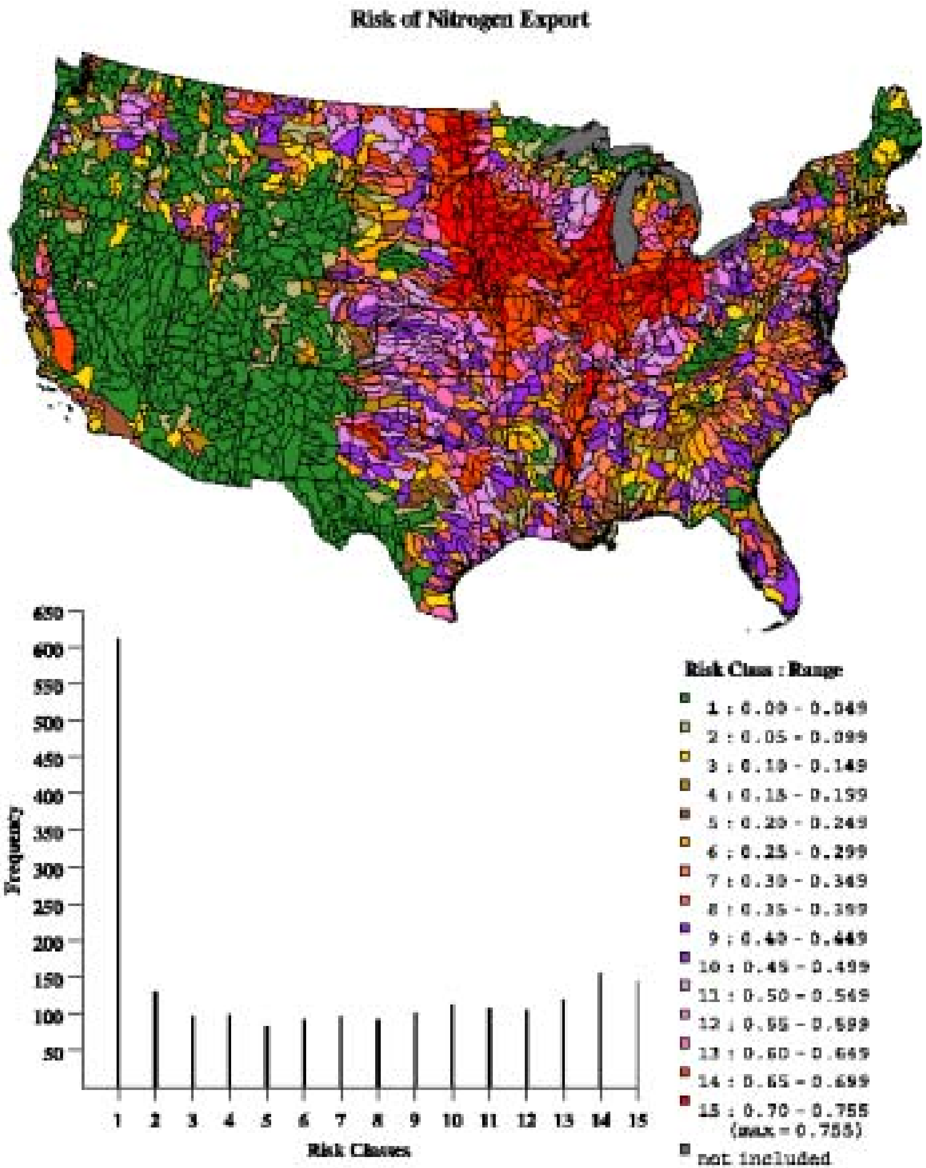

Nitrogen
Phosphorus
Probability of equaling or exceeding threshold
Proportion of forest
0.70
0.65
0.60
0.55
0.50
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0

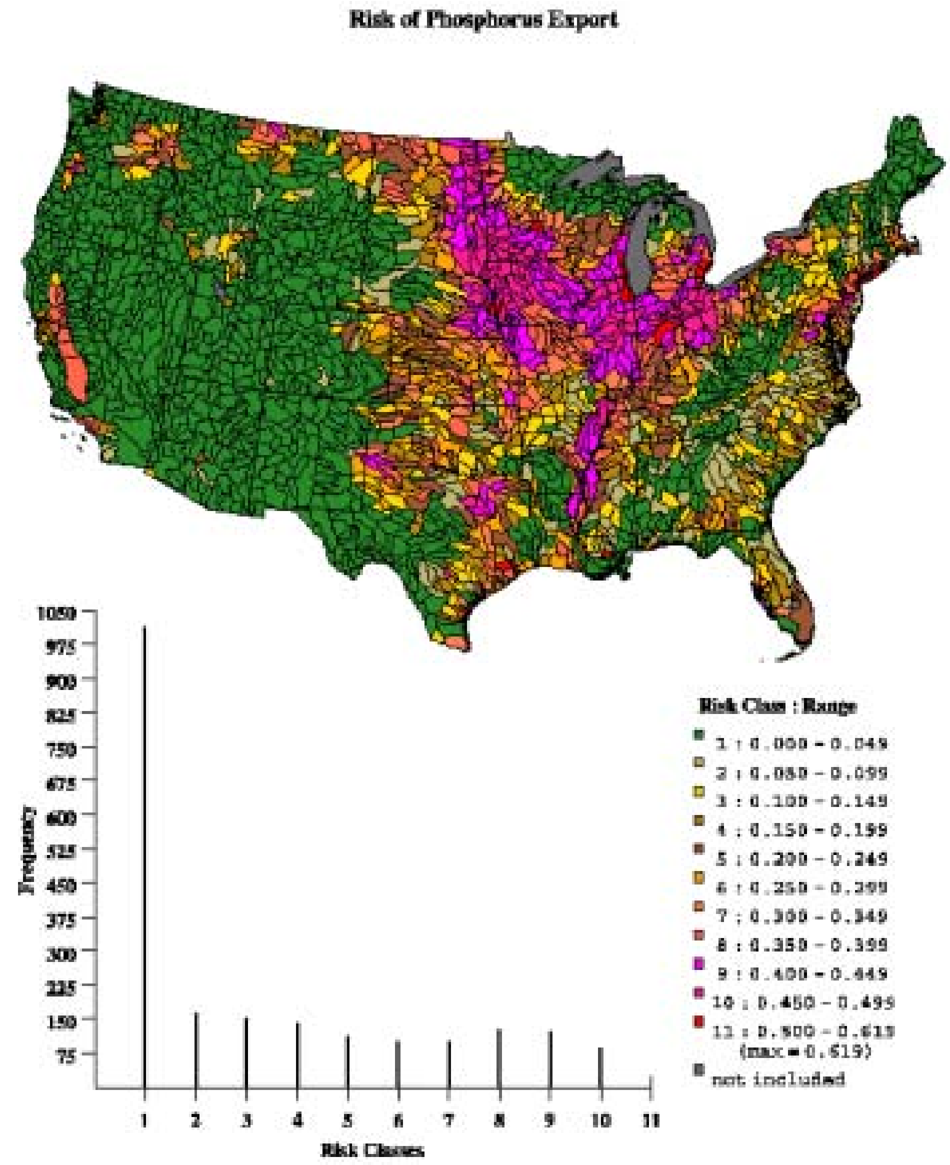


N $\geq$ 6.5 Kg/ha/yr
0.0 < p <= 0.15
0.15 < p <= 0.30
0.30 < p <= 0.45
0.45 < p <= 0.60
0.60 < p <= 0.77



P $\geq$ 1.1 Kg/ha/yr
p = 0
0.00 < p <= 0.14
0.14 < p <= 0.28
0.28 < p <= 0.42
0.42 < p <= 0.56


Risk of Nitrogen Export
Frequency
Risk Classes
Risk Class : Range
1 : 0.00 - 0.049
2 : 0.05 - 0.099
3 : 0.10 - 0.149
4 : 0.15 - 0.199
5 : 0.20 - 0.249
6 : 0.25 - 0.299
7 : 0.30 - 0.349
8 : 0.35 - 0.399
9 : 0.40 - 0.449
10 : 0.45 - 0.499
11 : 0.50 - 0.549
12 : 0.55 - 0.599
13 : 0.60 - 0.649
14 : 0.65 - 0.699
15 : 0.70 - 0.755
(max = 0.755)
not included

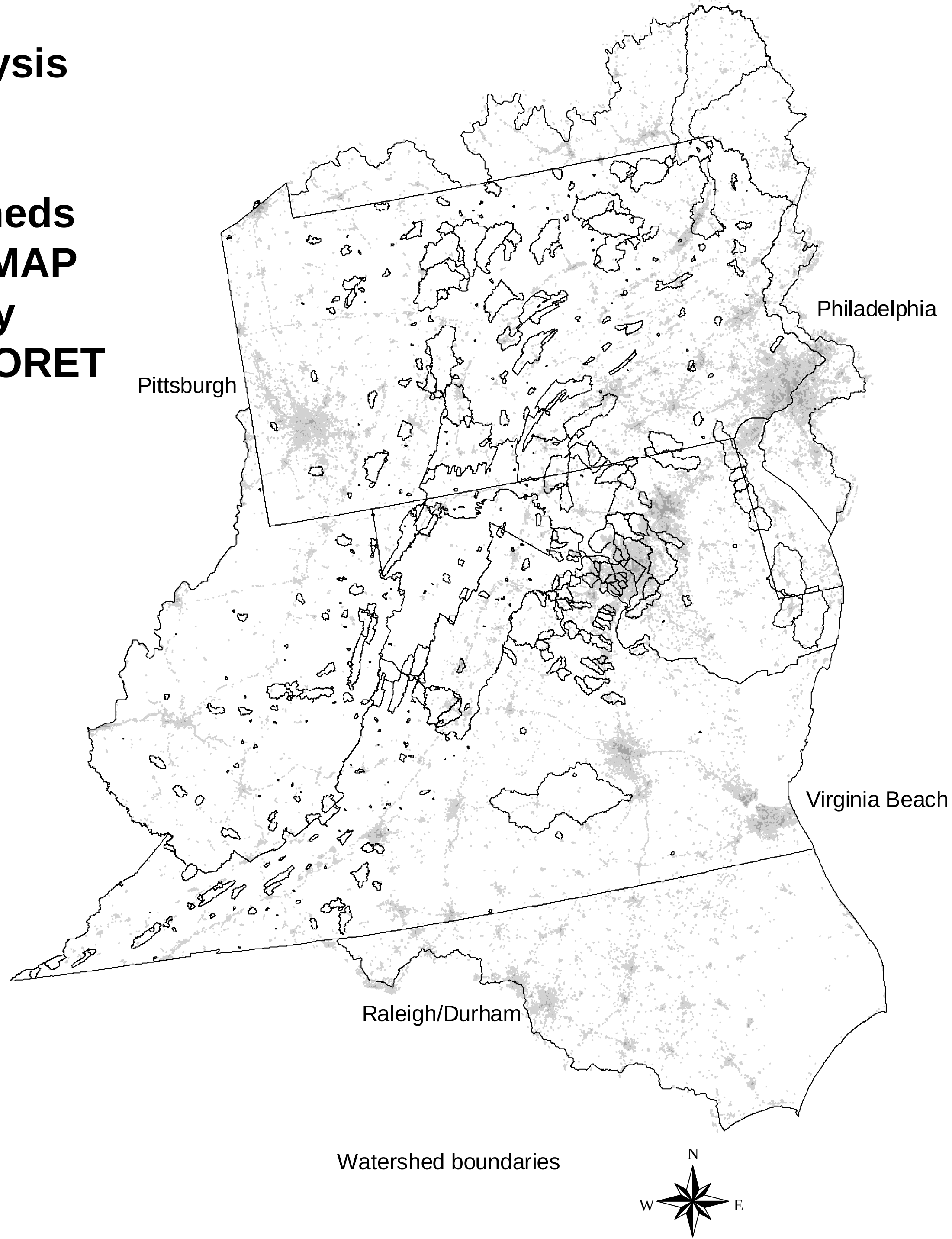

Risk of Phosphorus Export
Frequency
Risk Classes
Risk Class : Range
1 : 0.000 - 0.049
2 : 0.050 - 0.099
3 : 0.100 - 0.149
4 : 0.150 - 0.199
5 : 0.200 - 0.249
6 : 0.250 - 0.299
7 : 0.300 - 0.349
8 : 0.350 - 0.399
9 : 0.400 - 0.449
10 : 0.450 - 0.499
11 : 0.500 - 0.619
(max = 0.619)
not included

Classification and Regression Tree Analysis

Thresholds Established Inductively

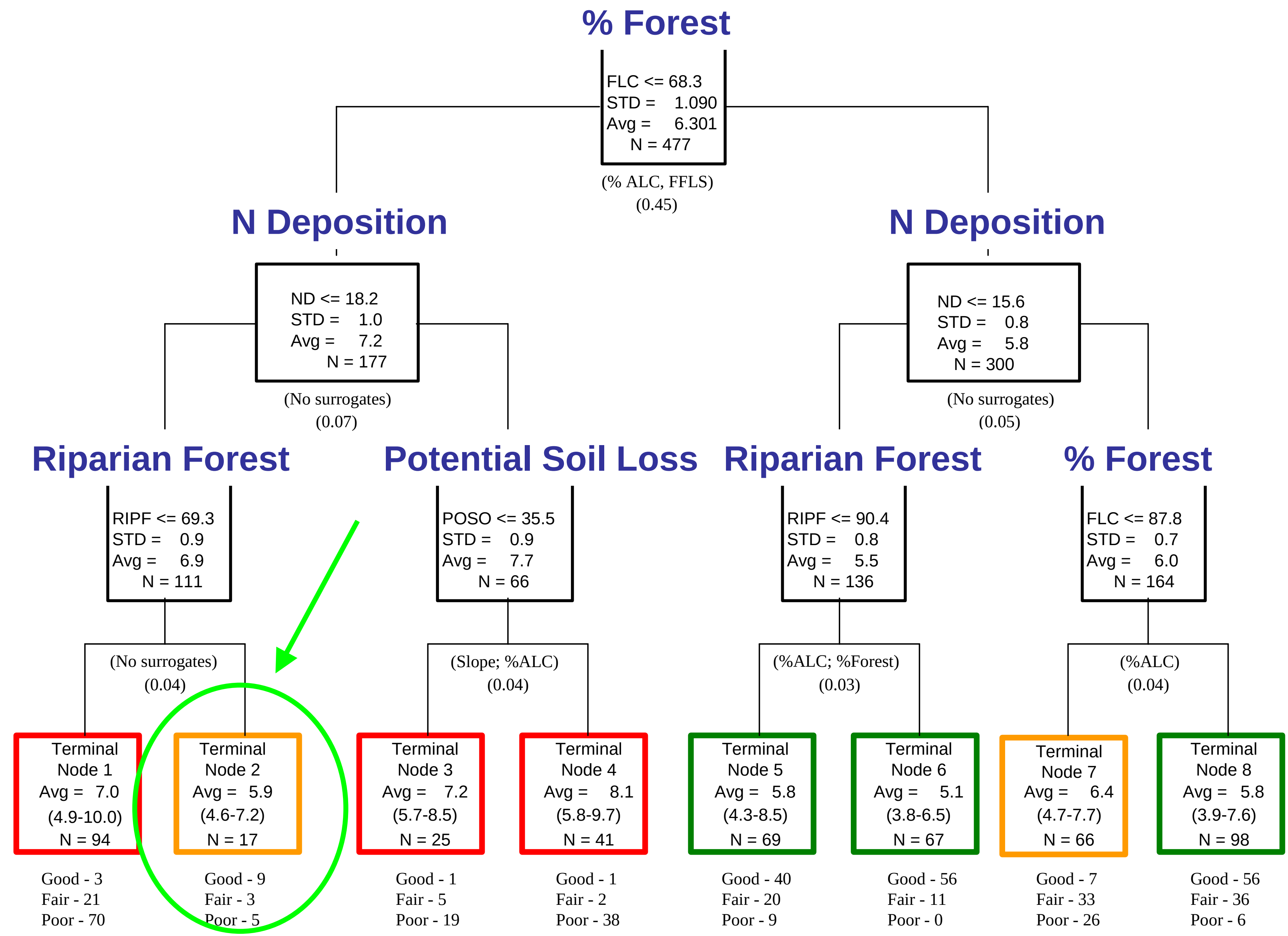
CART Analysis

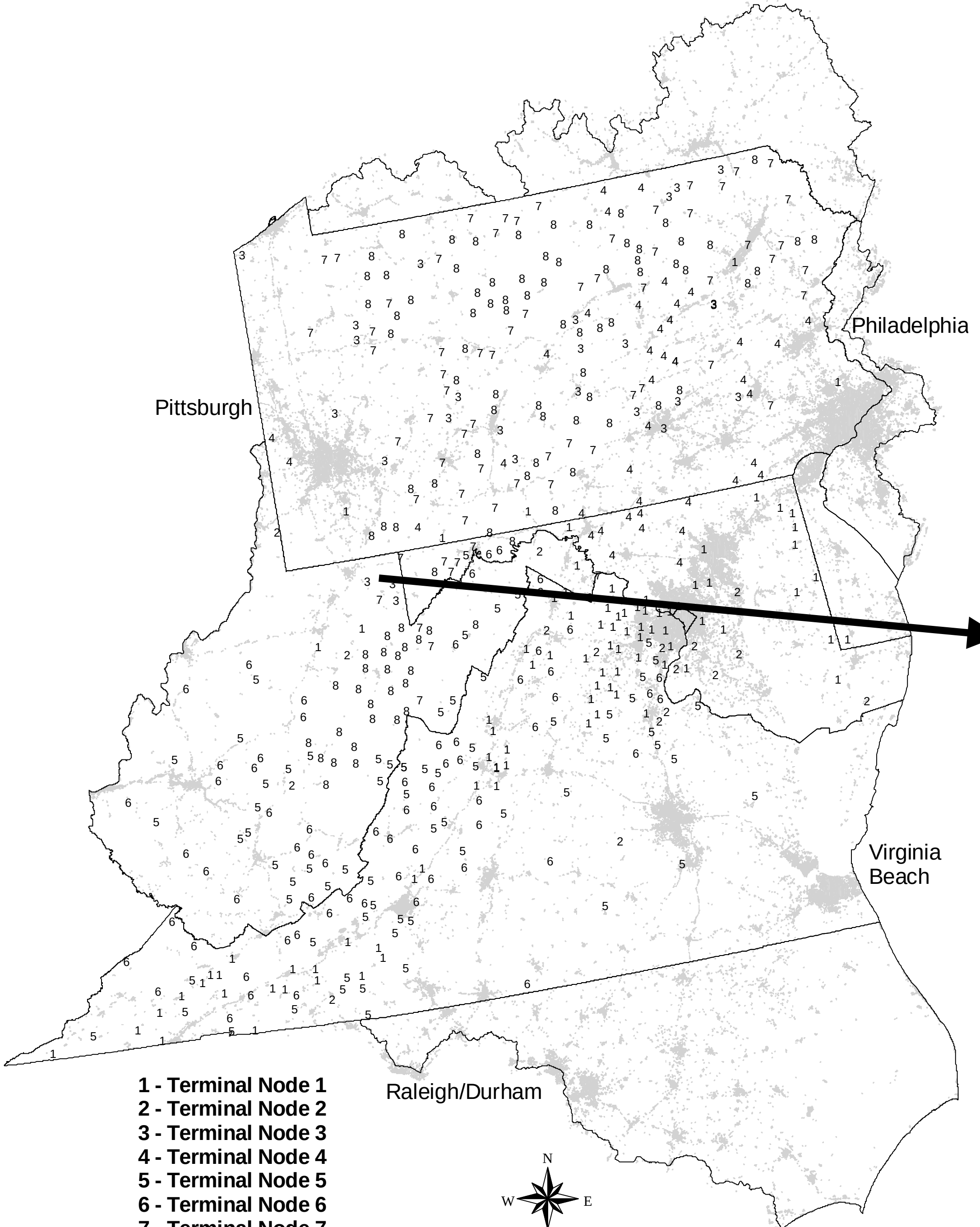
477 Watersheds Based on EMAP and carefully selected STORET sites



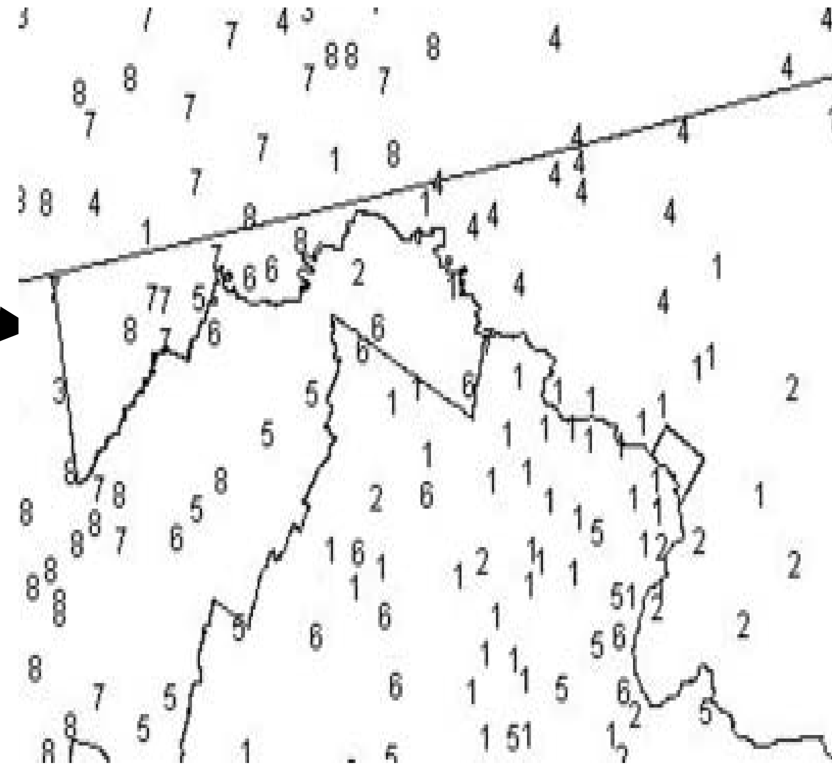
Watershed boundaries

CART Analysis – N concentration in MAIA Streams

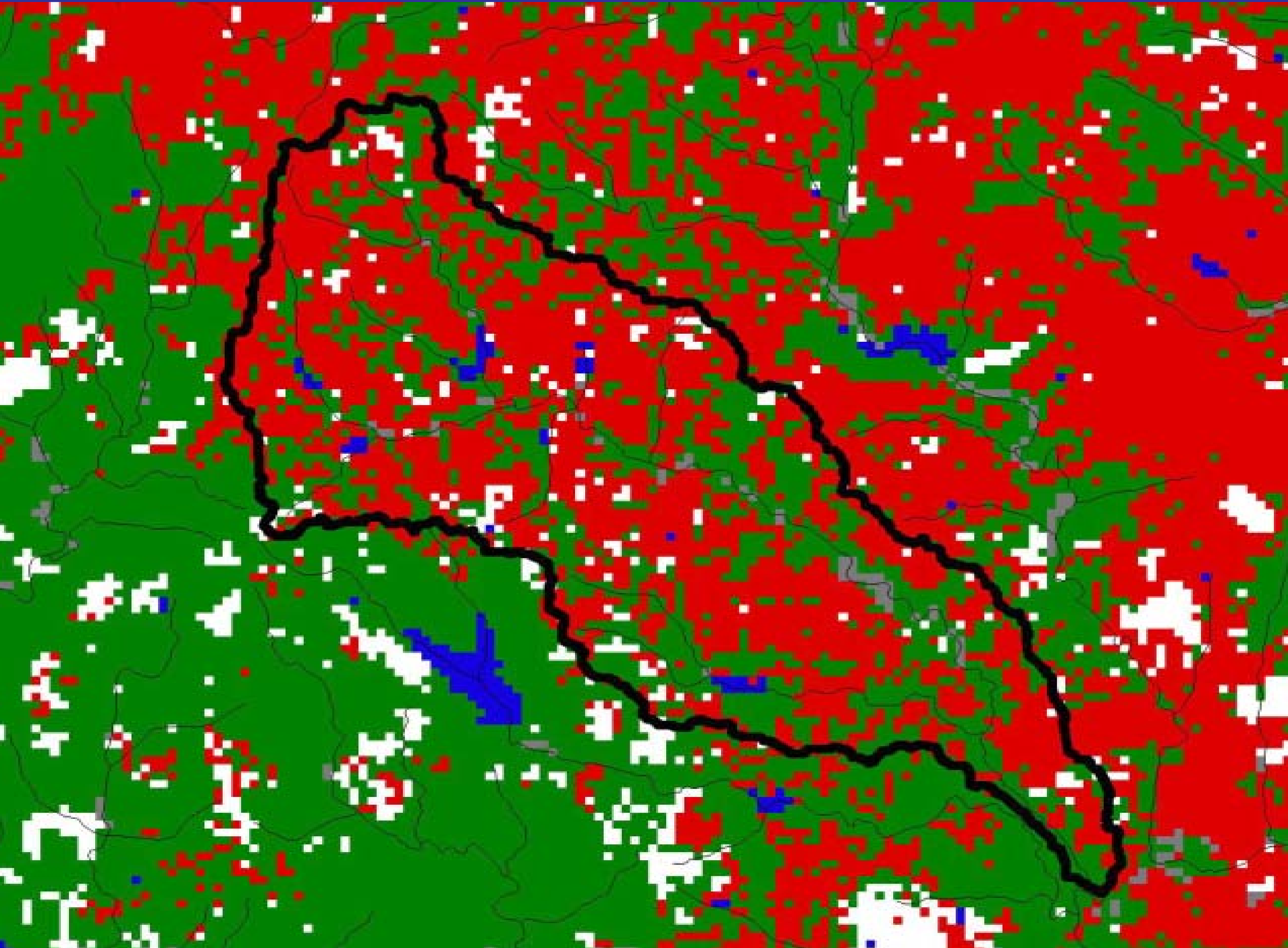




1 - Terminal Node 1
2 - Terminal Node 2
3 - Terminal Node 3
4 - Terminal Node 4
5 - Terminal Node 5
6 - Terminal Node 6
7 - Terminal Node 7
8 - Terminal Node 8



1 – poor
2 – fair
3 – poor
4 – poor
5 – good
6 – good
7 – fair
8 -- good



Conclusions

- Difficult to establish non-arbitrary thresholds because ecosystems are complex and constantly evolving … but thresholds and standards will be established!
- Biophysical classification schemes will be important in improving our understanding of thresholds … but one size doesn’t fit all!
- Landscape analysis and statistical approaches help evaluate a wide range of threshold approaches using existing data
- Landscape analysis and statistical approaches permit the mapping of uncertainty in exceeding thresholds based on landscape models and existing site data

Conclusions

- Need landscape metrics and indicators that capture horizontal interactions … to understand importance of position in the landscape and neighborhood influences
  - Linkage to hydrologic models that establish cell-to-cell flow networks
  - Distance metrics that weight individual cells and patches relative to their influence and contribution (Don Weller, Smithsonian)


The End
THE LITTLE RASCALS
.NET